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E7.8-10001
CR-155205

LANDSAT 2. PROJECT NO. 2896D

FINAL REPORT

(I) INTRODUCTION

Title: Water Utilization, Evapotranspiration and Soil Moisture Monitoring in the South-East Region of South Australia.

Assigned Investigation No. 2896D

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Reporting Date: 1 - 10 - 77

(E78-10001) WATER UTILIZATION, EVAPOTRANSPIRATION AND SOIL MOISTURE MONITORING IN THE SOUTH EAST REGION OF SOUTH AUSTRALIA Final Report (Bureau of Mineral Resources) 7 p HC A02/MF A01 CSCL 05B N78-11447 Unclas G3/43 00001

(II) TECHNIQUES

The techniques developed have been primarily orientated toward the land cover mapping component of the overall water utilization objective.

Photographic Techniques

The initial stages of the investigation involved using photographic material, including I:250 000 Black and White diapositives, prints and colour composite prints of Nov. 1972 and June 1973 imagery, with densitometric measurements taken from the B&W band diapositives. The photographic imagery was selected at this scale because it coincides with the national standard mapping scales for both topographic and geologic mapping. The imagery proved valuable in providing a general overview assessment of the area, but unsatisfactory in the development of a landcover methodology because;

(i) The costs of annual visual remapping were considered prohibitive.

(ii) The visual imagery was considered unsuitable for mapping at pixel resolution and was not considered suitable for discerning the subtle differences in radiance due to the different surface types that would need to be discriminated within the landcover mapping. The difficulty was in relating the visual record with a quantification that could be related to evapotranspiration characteristics. The evapotranspiration from grasslands is related to the greenness-dryness of the vegetation and it was considered that the photographic imagery would not provide the necassary reliability in determining greenness-dryness of the grasslands.

Densitometry was done on the I:250 000 B&W diapositives

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for the dates mentioned. The generation number of the imagery was such that the degradation on the film made any densitometric measurements unreliable. For this reason densitometry was not pursued and it was decided to utilize the digital data on computer tape (CCT) directly.

Digital Techniques

Digital data for November 1972, June 1973, December 1975 and January 1976 have been utilised in the study, to date. All the processing of the digital data has been done on a Cyber 173 computer with line printer output. This form of output has severely hampered the work of selecting training sets and portraying information, and created problems in understanding the resultant classification maps. In commencing this digital classification it was found that the state of the art classifiers (S of A) in particular the quadratic discrimant function classifier and the parallelopiped classifier, do not provide the resolution in landcover classes that were required for this project. This meant that it was necessary to develop a new classifier being called the Vector Classifier (Vec). The Vec classifier is a linear classifier in comparison with the S of A classifiers which are point classifiers.

The Vec classifier has been reported elsewhere.[1] The classifier has been verified in a number of situations;

(i) The mixed pixel situation of sand and scrub in the coastal zone of South Australia.[1,3]

(ii) Within turbid lakes in South Australia and Western Victoria.[1]

(iii) Within Bool Lagoon,[1] a large inland lagoon within the South East of South Australia containing a variety of water rushes and open water areas.

It is intended to verify the classifier for the grasslands of the South East before the classifier can be used in a general mapping program. To verify the classifier in the grasslands of the South East it was determined to be necessary to establish extensive field information within the area. To do this the visual imagery was used to select general topographic and geologically homogeneous regions in the South East provinces and within these areas training areas were selected so that they would be distributed across the provinces and also take into account the climatic variations across the area. By arrangement with the Department of Agriculture and Fisheries (DAF), an officer of that Department collected field information along selected road transects within the sample areas and at 36 day intervals designed to coincide with alternate LANDSAT overpasses. Colour and False colour photography were flown over the training areas with Hasselblad cameras in December 1975, considered to be the median point for likely successful imagery. Our problem was that at the time of collecting the field data, and the photography, we were not to know

whether the imagery was successful or not, and in fact did not find out this information until about three months after the overpass. As it turned out the 30th December 1975 and the 16th January 1976 imagery were successful in the South East and the 30th December LANDSAT imagery very closely matched the field information and the aerial photography. Having collected the field data and by utilising the flown photography, landcover maps were produced of the training areas, with each landcover class being identified by a 17 digit integer. These landcover maps have been digitised and will be matched to the imagery at the two relevant dates, so that detailed analysis can be undertaken on the relationship between landcover condition and spectral response in that image. The fact that we were not aware of the success or otherwise of the overpass for so long until after the event meant that the collection of field data was necessarily inefficient. Only two people could be employed on collecting field data for the nine month period, September 1975 to June 1976, with the result that much of the collected data was of no value to the project. A better alternative would be to have the same manpower used in collecting the information on only a few dates, for which it was known that the overpasses were successful, providing more data than we were able to, for a similar outlay.

(III) ACCOMPLISHMENTS

The overall objective is to relate measured soil moisture and evapotranspiration at Konetta Hydrological Station with repetitive ERTS imagery and so infer soil moisture and evapotranspiration conditions in other parts of the Region and to at least partially check the results in selected Sub-Catchments.

Whilst the project has not been completed a number of significant accomplishments have been achieved in the classification of land cover and its condition, a prerequisite to the eventual fullfillment of the overall objective.

(i) Development of a fine resolution Vector Classifier (Vec.)

The fine resolution classifier is not suited to be a general classifier but will provide a very fine resolution within a general class. The classifier assumes a linear change in response between the bands with changes in landcover type. The classification of each pixel is in terms of the proportions of the limiting response values for the particular landcover class, so that the very finest resolution that is practicable can be determined. The development of the classifier is similar to the mixed pixel concept first enunciated by Malila and Nalepka, and has been extended into a classifier suitable for mixed pixel situations as well as situations of environmentally changing surface types with demonstrated linear change in

response of one band against the other bands across that surface type. The derivation of the classifier and the evidence of the success of that classifier have been published elsewhere.[1,3] Evaluation of the classifier has been done in a number of situations.

a. The mixed pixel situation in the coastal zone of the South East of South Australia consisting of a mixture of the two surface types of sand and coastal scrub. In this case the classifier has been shown to give results that are very close to that that would be expected from the derivation, yielding reliable estimates of the areas of sand and scrub surface.

b. The turbid Lakes of the South East and in Western Victoria. These lakes have been shown to exhibit a linear correlation between the response values of the different bands with changes in lake condition so that the lakes could be satisfactorily classified to a very fine resolution with the Vec classifier.

c. Bool Lagoon, a large inland lagoon consisting of open water and areas of four different species of waterrushes was shown to have a linear correlation between the response values in the different bands, with changes in surface condition across the lagoon. Bool Lagoon has been mapped from LANDSAT on three dates and the continued existence of the linear correlation between the bands response values has been proven, although the reasons for that linearity are not known.

Whilst the Vec classifier can not be considered as a general classifier in the same way as current S of A classifiers can be, it provides a finer resolution than is capable of being achieved with the current S of A classifiers. It could therefore be considered as a second heirarchy classifier providing finer resolution in those classes previously classified by a S of A classifier, and within which the user requires a finer resolution than that provided by the S of A classifier. For example within the cases already mentioned or within the pasture lands where it may be required to get an estimate of the greenness-dryness or the bulk of the pasture, and where this cannot be readily obtained from S of A classifiers it is anticipated that it will be quite amenable to the Vec classifier. The Vec classifier only requires determination of the limiting response values and verification of the linearity condition. All intermediate pixels are classified in terms of these limiting response values, or nodes, as proportions of the nodes. With S of A classifiers however, training sets are required for each class and this is frequently impracticable, particularly towards the limiting cases because very few if any pixels consist of only the

true limiting cases, so that the classification is done using classes that would rarely be distributed in an optimum way along the linearity, and which will often have insufficient pixels within the training sets to provide reliable class statistics.

(ii) <u>Development of the concept of Vernier Control[2].</u>

One of the essential things that is required in remote sensing is the establishment of a viable and practicable method of providing spatial and radiometric control for the imagery. A method of determining or establishing position in the imagery to better than 1/10 pixel position has been proposed as a result of the LANDSAT program in the South East of South Australia. With this concept, mirror control points similar to that used by Evans of Stanford Research Institute will be established at an interval slightly greater than the pixel interval, so that along a line of pixels most of which are affected directly by response from a mirror, will occur a mirror not directly affected by a mirror. The position of this lower response pixel along the line of higher response pixels is related to the position of the first mirror within its first pixel working in exactly the same way as does a vernier. In this way we can get very reliable estimates of position, and misidentification can be eliminated as a significant source of error. It is our opinion that Landsat D imagery when provided with this sort of control could be used for 1:100 000 topographic mapping for landcover updating, and possibly even 1:50 000 series mapping also. The current imagery could be positioned to 1:100 000 mapping accuracy standards but the pixel resolution is too coarse for mapping at that scale. Work done here and in Canada using detail to match the LANDSAT imagery to ground control, has given standard errors in position of the adjusted pixels coordinates of the order of 0.4 pixel units (30 m).

Misidentification of control is a serious problem even when sharp boundary conditions exist as they did in our work in the South East and for the Canadian work along their northern coast. Misidentification remains a serious problem because the sampling characteristics of the scanner means that the resolution and characteristics of the LANDSAT imagery are quite different to the scene by an observer either on aerial photograph, a map or on the ground. This must lead to a measure of confusion as to the exact matching of a pixel to ground position. It is therefore essential that reliable methods of control are established in the imagery, for all situations.

(iii) The general accomplishment that has been achieved in this project is to prove that remote sensing is not only a tool, but is also an extension of man's sensing capability. It is only through his sensing

capabilities is man able to perceive his environment, and subsequently modify and improve that environment. Therefore remote sensing must reveal information about the environment not previously available, and indeed often not even known to exist. This must lead to a better awareness of the characteristics of our environment and subsequently to improvement in that environment. We believe that remote sensing is therefore not only an extension of mans sensing capability, but is also a tool to be used in environmental management.

(IV) SIGNIFICANT RESULTS

Within the wider application of LANDSAT imagery as developed during this follow-on project.

Mapping of the Coastal Zone

The South Australian Coast Protection Board is supporting a project to map the coastal zone using LANDSAT imagery, by the Vec classifier, with the purpose of investigating the application of the technique to management of the coastal zone. It has been established that reliable estimates of sand and coastal scrub areas can be determined from LANDSAT image classification by the Vec classifier more economically than by conventional means from a map of the coastal zone produced by photointerpretation using 1:10 000 aerial photography. Current LANDSAT imagery is also suitable for monitoring for large scale storm damage to the Zone, but the normal change in sand areas extent due to man's activity or other reasons, is about 5 to 10 m per year, occasionally being as great as 30 m per year, so that it is considered that LANDSAT D will have the resolution necessary to monitor these changes but not current imagery. The operational program will thus allow the Coast Protection Board to maintain surveillance on the coastal zone, to decide what areas need investigative or restorative action based on the LANDSAT evidence, and to inventory the resources of the coastal zone.

(V) PUBLICATIONS

1. "The Vector Classifier", McCloy K.R., Proceedings, Eleventh International symposium on Remote Sensing of Environment, Ann Arbor, Michigan, Apr. 1977.

2. "Geometric Fitting of LANDSAT Imagery", McCloy K.R., Bulletin, Remote Sensing Association of Australia, Vol. Number, , July 1977.

3. "The Application of LANDSAT imagery in Coastal Zone Management", McCloy K.R., Proceedings, Seminar on Applications of Remote Sensing to Coastal Management of the Coastal Zone, University of Sydney, Sept. 1977.

4. "The Application of Remote Sensing to Land Evaluation", McCloy K.R., Proceedings, Seminar on Land Evaluation, University of Adelaide, Sept. 1977.

5. "Report on Overseas Trip, 24 April - 20 May 1977", McCloy K.R. South Australian Institute of Technology, Adelaide, July 1977.

(VI) PROBLEMS

Two main problems have been encountered. The time taken to receive imagery after acquisition meant that a considerable expenditure of effort was made on collecting field data that subsequently was not required. Quick look facilities are essential to ensure the economical use of field staff both during the training and verification stages.

Lack of suitable hardware facilities on the computer proved to be expensive in the time resources of the researcher. It also meant that classification results were difficult to portray in a way amenable to understanding the classification.

In addition the soil moisture and evapotranspiration data for Konetta Hydrological Station contains apparent anomolies which are being currently investigated. As a result the programmed extrapolation of these conditions to other parts of the region is additionally subject to this restraint.

(VII) DATA QUALITY AND DELIVERY

Reference comments elsewhere in this report.

(VIII) CONCLUSIONS

Whilst the project has not been completed for the reasons given, nevertheless the hypothesis that evapotranspiration and soil moisture measurements at a single point can be extended over a wider area of the region by correlation with repetitive ERTS Imagery will continue to be actively evaluated. If validated, better evaluation of subcatchment and basin behaviour should result thus enabling an improved definition of regional water resources.

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6.10.77

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